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New York University
Constant Level Balloons Final Report
March 1, 1951

Technical Report No. 93.03

CONSTANT LEVEL BALLOONS

FINAL REPORT

Constant Level Balloon Project
New York University

Prepared in Accordance with provisions of Contract
W28-099-ac-241, between
Watson Laboratories, Red Bank, New Jersey
and
New York University

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ABSTRACT

Systems of constant altitude balloons have been designed, developed, tested and used in various types of atmospheric research. After investigation and testing of several methods, a system comprising of a plastic fixed-volume balloon, electrically operated control instrumentation, and liquid ballast was developed.

This system has been used on several series of flights for carrying instruments at constant altitudes, studying winds over long periods at the 200 mb level, and investigation of neutron maxima.

Balloon launchings were carried out at various sites in the United States by members of the project in coordination with representatives of the sponsoring agency. Meteorological analysis of conditions over selected stations in the Western Hemisphere as requested by the sponsor was carried out by members of the Department of Meteorology of New York University.

A. Introduction and Statement of Problem

Contract W-28-099-ac-241 between Watson Laboratories AMC was entered into on 1 November 1946 to be carried out from 30 September 1946 to 1 October 1948.

Services to be furnished were as follows:

Research, investigation and engineering services in connection with obtaining and furnishing experimental data on pressure and temperature in the upper atomosphere, to involve the following:

a. The securing of constant level balloons under the following conditions:

   (1) Initially a six to eight hour minimum time for the balloon in air; eventually a forty-eight hour time for balloon in air.

   (2) The altitude to be attained by the balloon will be 10 to 20 km, adjustable at 2 km intervals.

   (3) Maintain elevation within 500 meters and the frequency of oscillation to be such that it will not interfere with operation of balloon borne radio equipment.

b. The construction by the contractor of an experimental air borne radio and associated air borne or ground receiving equipment which will transmit and receive information from a mechanical movement introduced into the radio circuit. The weight of the pick up device and any required power supply to be carried in the balloon will not be over 2 lbs.

c. The contractor will fly the balloons, track them, and collect the data on pressure and temperature to be transmitted as the balloon goes up and at periodic intervals at flight altitude. These intervals to be determined by consultation. The accuracy is to be comparable to that of the standard Army Radiosonde.

d. Interpretation of Meteorological data in connection with project.

Five copies of reports of design and development phases were to be delivered at monthly intervals. Results of meteorological studies were to be transmitted as completed to the sponsoring agency for use of Air Force scientific personnel.

On 27 February 1948, Modification #1 revised the number of copies of reports to be furnished to 25. Modification #2, of 2 April 1948, added the requirement of "Research Investigation, and Engineering services leading to the determination of the dependance of the propagation of sound on atmospheric conditions", to the contract. Contract funds were increased to cover this additional requirement.

Under Modification #3 of 23 April 1948,it was agreed that a separate final report on telemetering from Balloon Systems would be completed and transmitted to the sponsor. The time of performance was extended to 1 February 1949 and contract funds increased to cover the increased period of performance by Modification #4 to the contract on 29 September 1948.

On 28 October, 1948, the number of reports required was increased to fifty (50) and the place for final inspection and acceptance charged to Cambridge Field Station, AMC by Modification #5. Modification #6 changed the allotment for funds to be used on the project. The period of performance of the project was extended to 30 March 1949, by Modification #7 of 26 January 1949.

Modification #8 of 8 April 1949, modified the requirement to that of maintenance of one trained person in the field to carry out balloon launching and tracking services in conjunction with Air Force scientific personnel. Funds were increased to extend the period of performance to 15 March 1950. A final report on development and testing of constant altitude balloon systems was to be submitted to the Air Force. Modification #9 revised the delivery address for reports.

Modification #10 of 1 May 1950, increased contract funds to continue field service and meteorological analysis work to 15 June 1950.

Modification #11 subsequently extended the period of performance to the termination date of 31 December 1950 and increased funds accordingly.

B. Constant Altitude Balloon Systems

Development of a system to maintain balloons at constant altitudes for long periods of time was completed on 15 March 1949. This development has been completely reported in "Technical Report 93.02"(1) by this Research Division under "Section 1, General".

Essentially the system as developed at New York University consists of a constant volume balloon of thin polyethylene which, when filled with hydrogen or helium, furnishes the lift for the system. (Because of the increased safety to personnel and equipment, use of helium is to be recommended). The balloon is inflated with enough gas to balance the weight of the suspended equipment, plus a certain amount of "free lift" which will cause the system to ascend. When the balloon nears floating altitude and becomes full, the gas comprising the "free lift" will be expelled through an open appendix at the bottom of the balloon. The system is then at equilibrium at an altitude fixed by the balloon volume. The ratio of molecular weights of the lifting gas and air, density of the surrounding air, and the total balloon load are as follows:

$$V_b \left(1 - \frac{M_g}{M_a}\right) d_a = L$$

This state of equilibrium is broken, however, by changes in any of the above variables. Basically, losses of lift due to leakage and diffusion of gas, and changes of temperature of the lifting gas cause a change from equilibrium conditions.

Any variations causing an increase in altitude will result merely in a valving of gas from the fixed volume balloon and a slight increase in altitude. Changes in the reverse direction, however, must be compensated for by decreasing the load on the system to prevent descent to the ground.

This decrease of load is carried out by dropping liquid ballast as demanded by a pressure activated ballast control switch. This switch completes a circuit through a relay operated ballast valve whenever the balloon system descends to a region of pressure greater than that of its selected floating altitude. Ballast is thus dropped and the system returned to floating altitude.

On flights made on another project since the termination of the development phase of this project, the ballast control system was standardized to include a pressure displacement switch and an electrically operated ballast valve. The displacement switch (Fig. 1) consists of a standard temperature compensated aneroid cell and pen arm from a radiosonde modulator

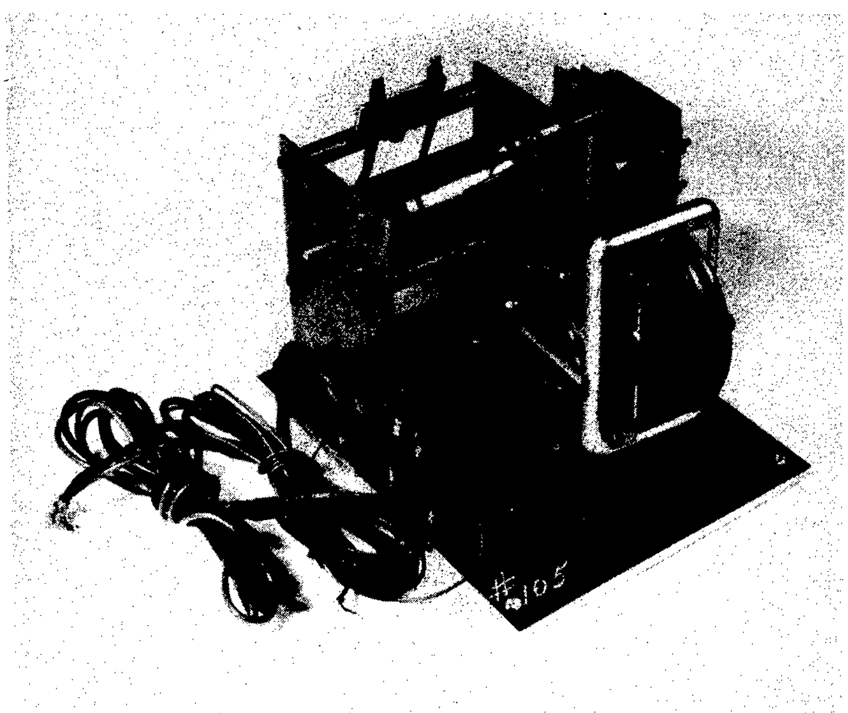


Fig. 1
Pressure Displacement Switch for Ballast Control

(Type E preferred); a rotating commutator of two segments, an insulator and a conductor; a six volt 1 rpm motor; and a shelf for the pen arm. In calibration, the aneroid cell is moved across the base by means of a screw which allows selection of various altitudes for control.

Initially the pen arm rides on the shelf during ascent so that the circuit to the valve remains open until the balloon approaches floating altitude. Several thousand feet before ascent is completed the pen arm falls off the shelf closing the ballast circuit (Fig. 2) and causing ballast flow during the final period of ascent. When the balloon reaches control

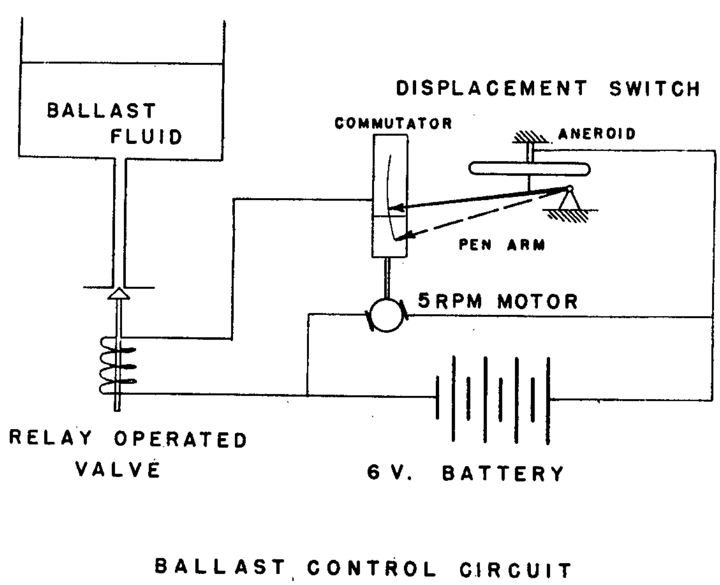


Fig. 2
Ballast Control Circuit

altitude the pen passes to the insulator portion of the commutator and ballast flow ceases. Whenever the balloon system subsequently descends past control altitude, ballast is made to flow, maintaining the balloon altitude at control level. This system has been used successfully on over twenty constant level flights maintaining altitude to close limits for periods up to 60 hours. An example of a flight made with this control is shown as Fig. 3.

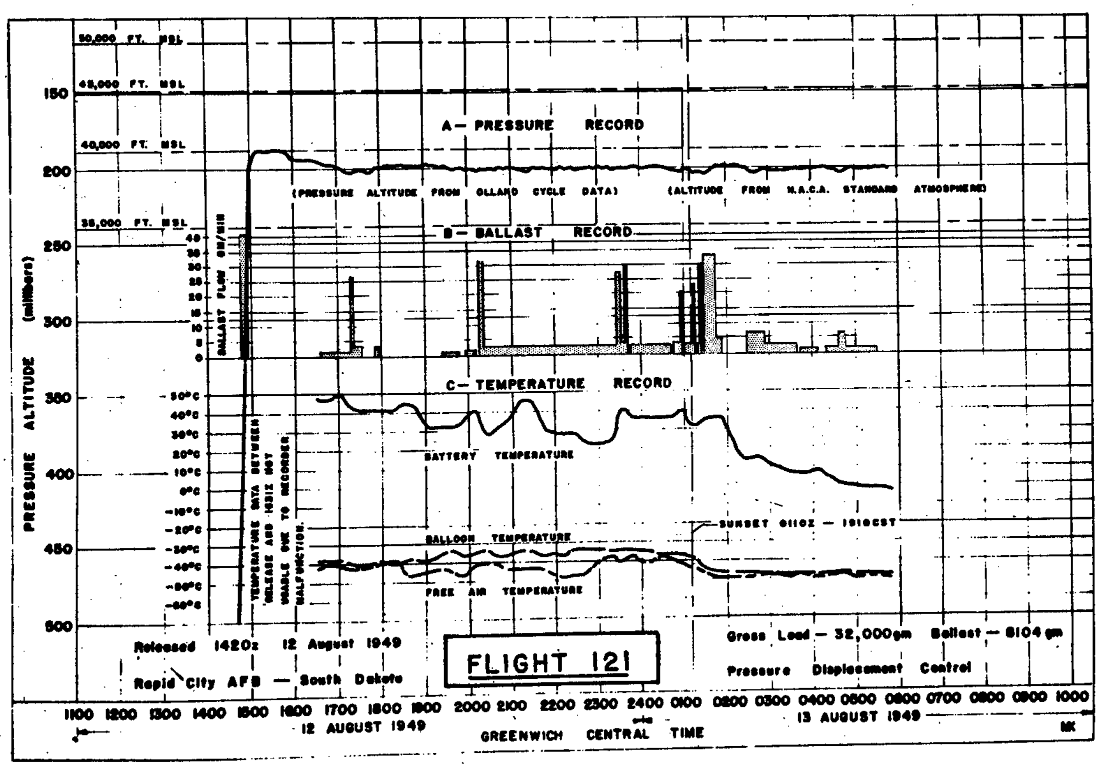


Fig. 3
Constant Level Balloon Flight Using Ballast Control

A review of this system by members of the University staff has been published in "Transactions of the American Geophysical Union[2]". Earlier work on this development has been reported by members of this Research Division in "Technical Report 93.01"[3] and in the "Journal of the American Meteorological Society"[4].

A manual for those interested in making use of balloon systems of this type has also been published as "Section II, Operations" of our "Technical Report 93.02"[1]. This report consists of a discussion of instrumentation for balloon systems, techniques for launching and tracking, and telemetering from balloons as developed and tested at New York University.

C. Telemetering From Balloon Systems

The second requirement of this project was the investigation, development, and testing of balloon borne telemetering systems. The development was completed in June of 1948 and a final report[7] of work accomplished and recommendations made to the sponsor at that time.

Two types of transmitter units were suggested as a means of accomplishing the telemetering of data from a balloon to ground station receivers. A high frequency system, making use of line-of-sight transmission allows for accurate positioning of the balloon system from two ground stations. The line-of-sight characteristic, however, limits the range of this type transmitter, and ranges in excess of 250 miles are not to be expected with a balloon system floating at 40,000 ft.

Three line of sight transmitters were designed for use in balloon work. The first, the FM-1, was designed to operate at 72 mc, using a conventional reactance tube modulator. Several stages were included to deliver 1 watt output at the design frequency. The unit was quite complicated and the required input power large due to the requirement for several stages to transmit at the high frequency. Fig. 4 is a schematic of the FM-1 transmitter.

In order to overcome this limitation of FM sets, a two tube transmitter was developed (Fig. 5). Variation in vacuum tube resistance is used to modulate the oscillator plate voltage of a self-excited oscillator in accordance with the audio signal. This provides the frequency modulation desired. In order to maintain a stable center frequency and render the oscillator insensitive to changes in supply voltage, a neon tube voltage regulator was included.

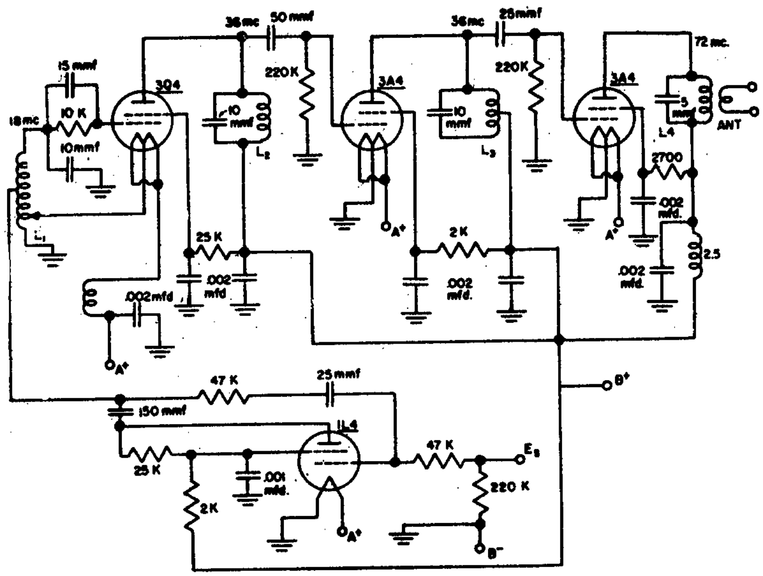


Fig. 4
FM-1 Transmitter

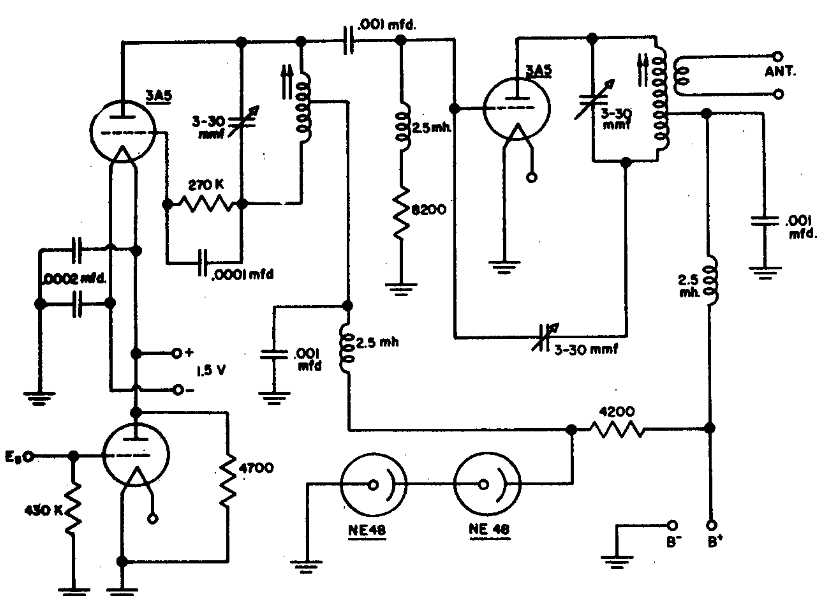


Fig. 5
FM-2 Transmitter

Output of the oscillator is both amplitude and frequency modulated, the amplitude modulation being limited by a class "C" RF amplifier. This unit weighed six ounces, was fed by a plate voltage of 270 volts with a filament drain of 400ma. at 1.5 volts. The output was one watt at frequencies from 25 to 100mc.

Before procurement of a receiver with automatic frequency control an attempt was made to develop a crystal controlled oscillator to overcome the frequency drift inherent in FM systems. This work was abandoned when the controlled receiver was obtained. The crystal control unit which was developed required extreme care in tuning in order that modulation be linear.

A miniature power amplifier, using one dual triode as a push-pull amplifier was constructed for use at 25 to 100mc with any of the above mentioned transmitters. The antennae for these transmitters was a half-wave vertical dipole.

The receiver found satisfactory for these systems was the R-2A/ARR-3 Sonobuoy receiver. This unit employs Automatic frequency control and will tolerate a drift $\pm$ .35mc before retuning is required.

When SCR-658 radio direction finding equipment became available work on these transmitters was abandoned and a 400mc transmitter used. This system allows for accurate positioning of the balloon systems by use of crossed azemuths from several receiving stations.

A transmitter using pulse time modulation was designed for use with this receiving equipment. The advantages here are high peak power with relatively low input power (and thus a high signal to noise ratio) and simultaneous transmission of several data channels at one frequency. This project was abandoned before tests could be completed due to a modification of project requirements, but preliminary results indicated that this system would be advantageous in AM or FM transmission. This system makes use of short duration pulses (.5 micro second) at a repetition rate of approximately 10 kc.

For long range transmission of information an amplitude-modulated transmitter was developed. (Fig. 6) This unit, the AM-1, is crystal controlled, employing a 3A4 miniature tube in a Pierce oscillator circuit as the crystal oscillator. This circuit does not require an LC tank circuit and eliminates the tuning of this additional stage. The RF amplifier is a 3A5 miniature dual triode tube. The unit was designed to give 1.5 watt output with a 270 volt plate supply and can be used with 380 volts to give 3 watt output.

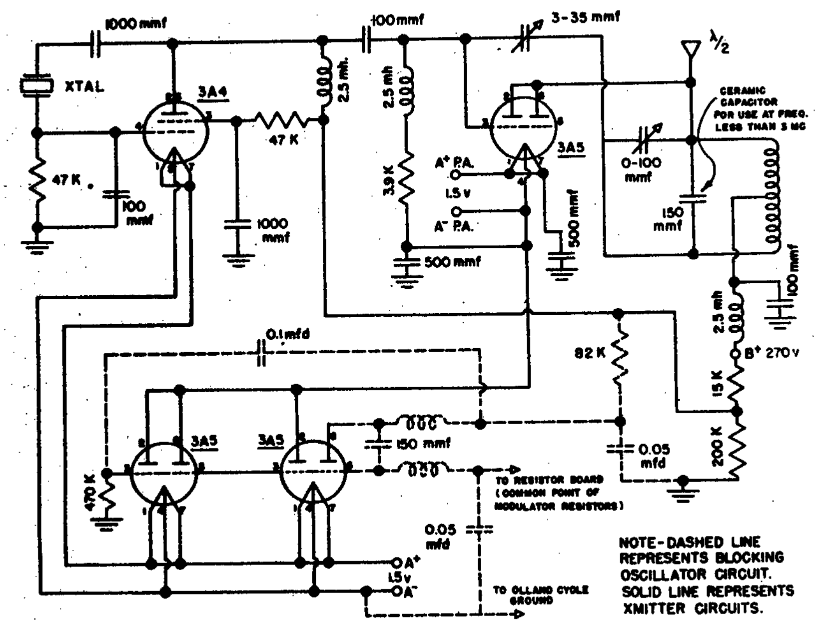


Fig. 6
AM-1 Transmitter

Frequency ranges from 1.5 to 9mc can be employed with the AM-1. The modulation of the AM-1 is effected by use of a triode modulator (2-3A5) tubes) connected in series with the plate supply of a class "C" RF amplifier. Variation of the plate supply voltage of the RF amplifier caused by change in tube resistance gives amplitude modulation linear with plate voltage of the amplifier. By use of this system modulation from DC to several hundred cycles is obtained.

The receiver for this transmitter was a Hammerlund SP 400X with several modifications. In order to increase the signal to noise ratio a crystal filter was introduced into the IF amplifier circuit to narrow the bandwidth. Bandwidth was also reduced by decreasing the coefficient of coupling between the primary and secondary of the IF transformers. By this reduction of bandwidth to 3kc a 3 microvolt signal produced a 15.5 DB signal to noise ratio, where at 16 kc bandwidth only 7 DB was obtained.

In order to obtain accurate reproduction of the amplitude of the audio frequency the AVC circuit was modified by adding a fixed bias to the AVC diode of the receiver. This flattened the characteristic of the AVC circuit and no change in amplitude of recorded audio signal was detected over a six hour flight using a constant amplitude audio signal from the transmitter. The signal was tapped off at the output of the second detector of the receiver and fed to a Brush BL 905 AC amplifier for recording. The recorder used was a Brush BL-202 double channel oscillograph. A quarter wave vertical receiving antennae was employed with a counter poise ground. The transmitting antennae was a vertical half wave dipole.

In order to use the AM-1 for transmission of information from pressure and temperature sensors a relaxation oscillator circuit was incorporated in the system. (dotted section - Fig. 6). This oscillator used one half of one of the 3A5 modulator tubes and produced a blocking rate approximately proportional to resistance of the sensor instruments. This information could be superimposed on the regular modulated signal and two types of information could be transmitted simultaneously; one as an amplitude and frequency change of the basic signal, the other as a frequency of pulses superimposed on the basic signal.

The AM-1 has been used in balloon control research to transmit information on pressure, temperature and ballast requirements. It was also employed to give information on Neutron intensities in another Air Force project[5]. In order to obtain information on balloon position on a wind study project the AM-1 was used as a beacon to be "homed in" on by the radio compass of aircraft[6].

A system of diversity reception was considered for use with a dual channel AM-1 transmitter in order to increase reliability despite atmospheric noise. In the dual channel unit a common modulator was connected to two separate crystal oscillators and RF amplifiers. In preliminary tests two receiver and recording units were used.

For short range balloon flights the AM-1 was modified for use with subminiature and acorn type tubes. In this, the AM-2, two 2E27 tubes in parallel provide excitation for the type 958A RF amplifier. A circuit diagram of this unit is shown as Fig. 7.

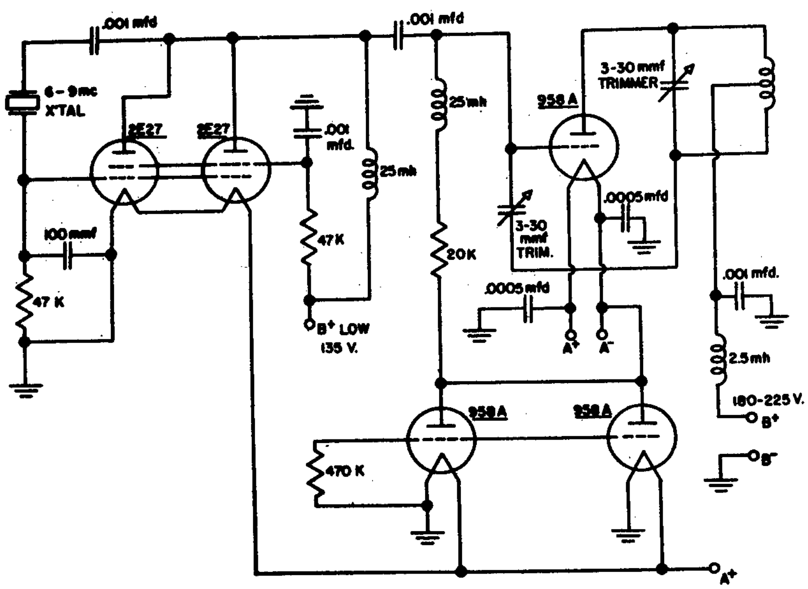


Fig. 7
AM-2 Transmitter

In addition to radio direction finding with the SCR658 and beacon transmission with radio compass, several other methods of balloon positioning were evaluated. Radar positioning was successful only if a target was attached to the balloon train. Generally, the ranges possible with radar are not as great as those possible by radio direction finding. For direction finding on the low frequency AM transmitter some value was found in use of loop antennae. Accuracy of this method is between .5 and 2 degrees and is generally hindered by sky wave reflection.

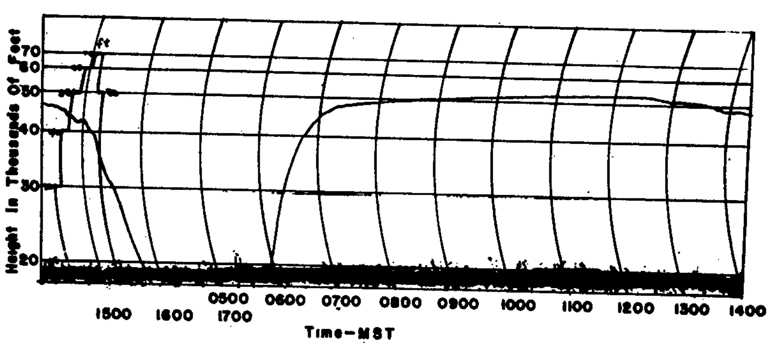
A pulse time modulated transponder beacon at high frequencies was found to be advantageous for obtaining accurate slant range to the balloon. Preliminary investigation of use of Doppler effect for positioning indicated that this method is not feasible due to difficulty in measuring the low frequency differences involved.

D. Launching Services

During the course of the project balloon flights were split into two general classifications, (a) research and (b) service.

Research flights were made to test balloon controls and telemetering systems developed under the contract. A full report of these research flights has been made in "Technical Report 93.02 (1), Section III, Summary of Flights"

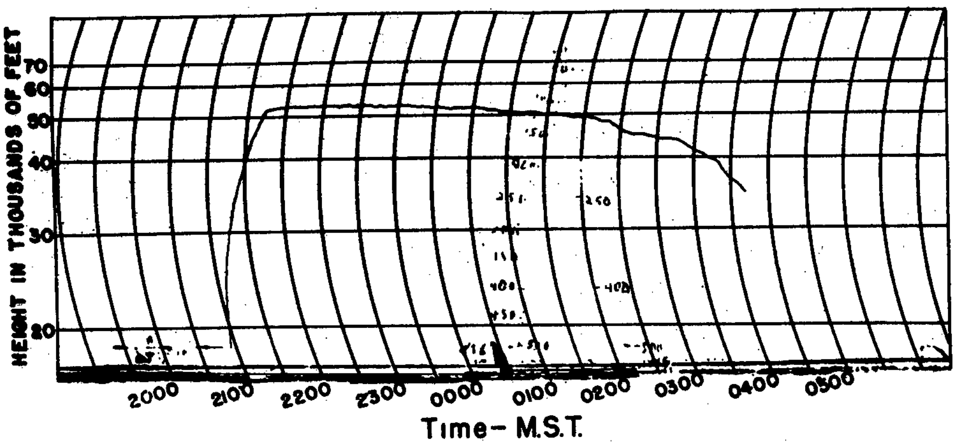
Service flights were carried out by New York University personnel in conjunction with technical personnel from the sponsoring agency to test geophysical equipment developed in Air Force laboratories. The requirements for these flights were launching and tracking of balloons to float at specified altitudes for short periods of time (6 to 8 hours). Because of this short flight duration, simplified plastic balloon systems were used. Balloons were maintained aloft by use of constant fixed ballast flow, or ballast was excluded entirely from the system. A typical flight using constant ballast flow at a rate slightly exceeding leakage losses is shown as Fig. 8.



NYU BALLOON PROJECT FLIGHT 82
Barograph Record Of G.M. 20' Plastic Balloon With
534 gm/hr Fixed Ballast Leak
RELEASED AT ALAMOGORDO, N.M.– 0511 MST, 10 AUG 1948
DESCENDED AT ROSWELL, N.M.– 1630 MST, 10 AUG 1948
DURATION– 11½ hrs

Fig. 8
Balloon Flight Using Fixed Ballast Flow

Fig. 9 is a typical flight with no ballast. The flight train for these flights is shown as Fig. 10.



NYU BALLOON PROJECT FLIGHT 71
Barograph Record Of G.M. 20 Ft. Plastic Balloon Showing Balloon Performance When No Ballast Was Dropped
RELEASED AT ALAMOGORDO N.M., 2042 MST – 9 JULY, 1948
RECOVERED AT VALENTINE TEXAS, 10 JULY, 1948
ESTIMATED DURATION 10 HOURS

Fig. 9
Balloon Flight Without Ballast

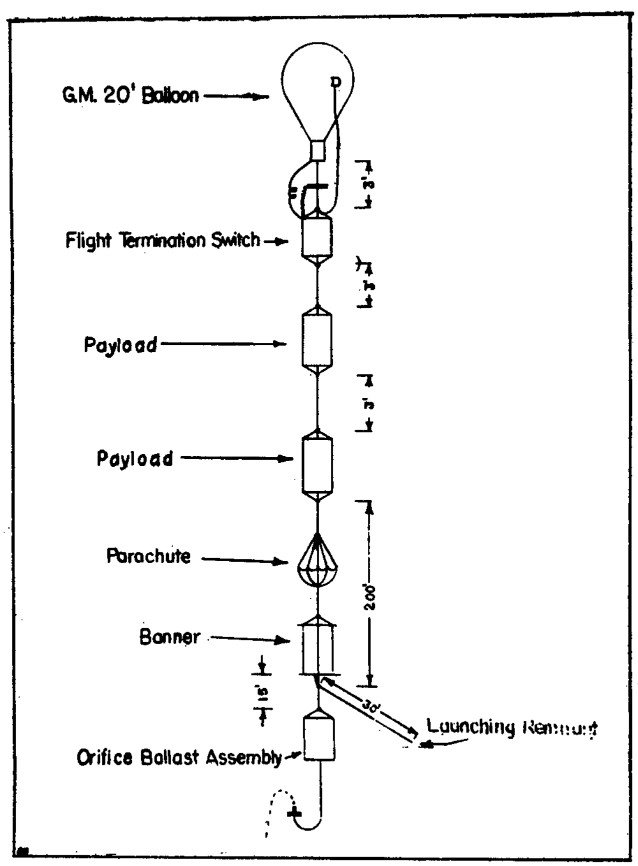


Fig. 10
Flight Train, Service Flight

With light weight payloads, balloon systems of this type can be launched by two or three experienced balloon men. The launching is carried out in a manner similar to that explained in Section II, Operations, of "Technical Report 93.02[1]," in that the balloon is inflated in the lee side of a building or wind screen, (or in an aircraft hangar if one is available, or in the open when winds are light) with the equipment train laid out downwind of the balloon. The amount of gas lift is equal to balloon weight plus approximately 10% to cause ascent at 800 to 1000 ft. min. A picture of inflation of a 20 ft. diameter plastic balloon is shown as Fig. 11.

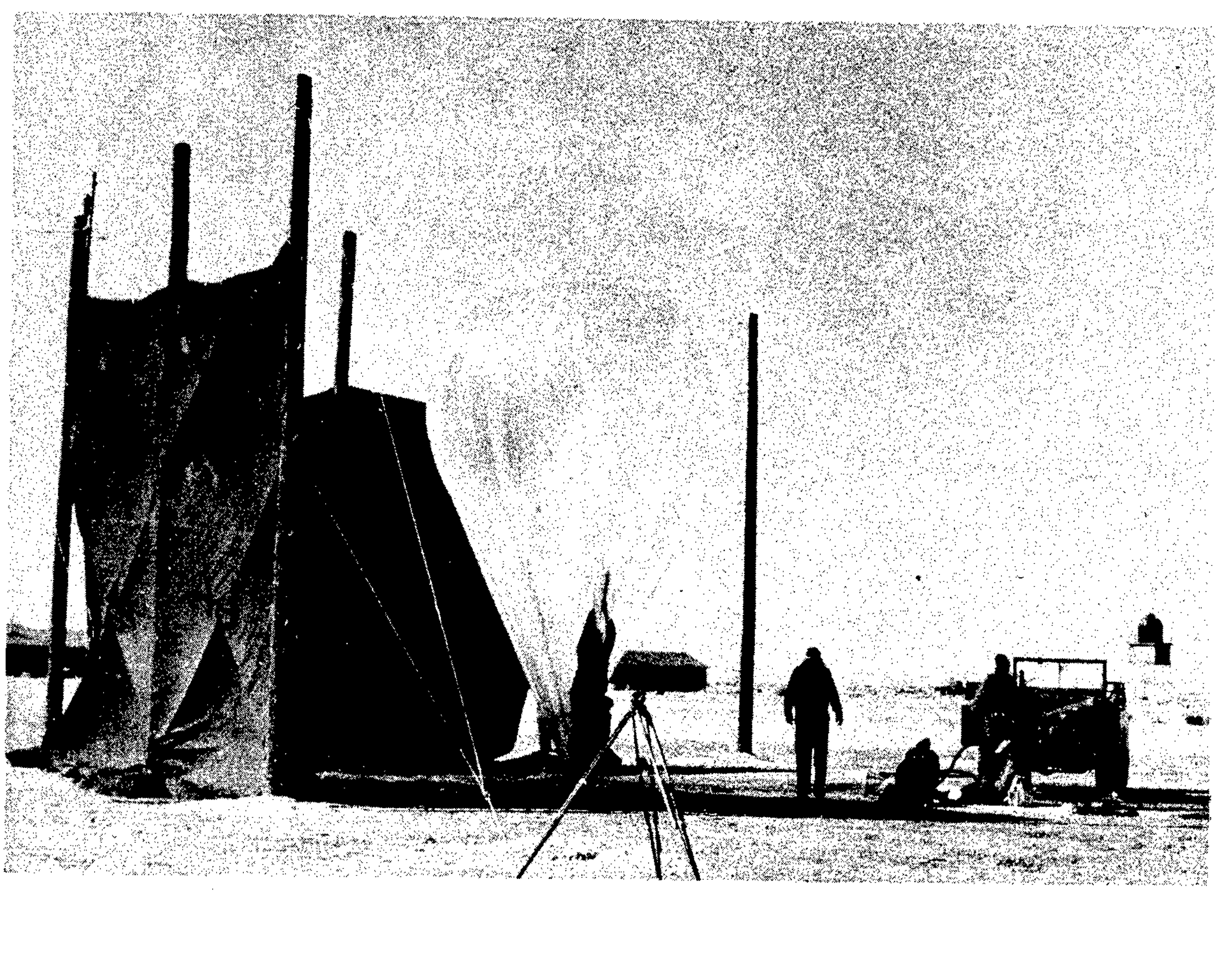


Fig. 11
Inflation of a 20 ft. Plastic Balloon

The following is a list of equipment needed for launching of a single flight of this type:

(a) Launching Equipment:

1 ea. set instructions (Operations Manual)
2 ea. elliptical shot bags (each filled with 100# of shot)
1 ea. 40' x6' Ground Cloth
4 ea. sheets polyethylene, .001" to .004", 4' x 4'
1 ea. gas tank manifold with pressure gages and valve
1 ea. rubber hose, 1" I.D., 10' long with diffuser
1 ea. rubber tubing 1/2" bore, 1/8" wall, 8' long
1 ea. solution balance
1 ea. inflation nozzle, ML-196 for rubber balloons

1 ea. tool kit complete with 2 sheath knives, 50' cloth measuring tape, brass wire, 1" Mystic tape, volt ohmmeter, pliers, screwdrivers, inflation tools, flashlights, crescent wrenches, soldering iron, compass, 2 open-end wrenches, 1-1/8" x 1-1/4" openings, 14" pipe wrench, spanner for helium tank valves, etc.

1 ea. theodolite ML-247 with tripod ML-78 (optional)
1 ea. recorder, brush oscillograph or other with amplifier.
1 ea. SCR-658 radio direction finder
1 ea. chronometer

(b) Flight Equipment:

2 to 5 tanks helium
1 ea. balloon
2 ea. rolls acetate fiber scotch tape
1 ea. appendix stiffeners (if appendix is to be used)
500# test nylon line
75# test linen twine
2 ea. 350 gram balloon ML-131A (for wind sock)
5 to 10 toggles or hooks
1 ea. radio transmitter
1 ea. pressure sensor (and temperature if desired)
Payload instrumentation
1 ea. banner, 3' x 6'
Data sheets
Weight sheets
Reward tags (English, Spanish or other language)

(c) Termination Equipment

1 ea. flight termination switch
1 ea. set rip rigging
2 ea. cannons
2 ea. squibs (treated for high altitude)

(d) Fixed Rate Ballast Equipment: (optional)

1 ea. orifice spinnerette, to give proper ballast flow
1 gallon ballast, compass fluid AN-C-116
1 ea. ballast reservoir (1 gallon capacity)
1 ea. filter 3' diameter, 325 x 325, phosphor bronze mesh
6 inches tubing (Tygon) 3/16" bore

Tracking of these flights was maintained by use of an SCR 658 radio receiver with a 400mc transmitter telemetering information from the balloon system. Information received through the telemetering circuit can be recorded on a standard weather station recorder, a recording oscilloscope of the Brush Development type or by any other convenient means.

Altitude of the service flights was determined by use of a modified radiosonde modulator, an olland cycle modulator (see p.68 , Section I, General, Technical Report 93.02(1)), or by computation from knowledge of the weight of the balloon system and volume of the balloon.

In order to keep balloon systems from floating in the air lanes, a flight termination switch was included in the circuit. This switch is a radiosonde modulator modified so that all contacts above 25,000 ft. are disconnected from the circuit. The pen arm rides on a shelf during ascent to about 30,000 ft. and then falls to the commutator (See Fig. 12).

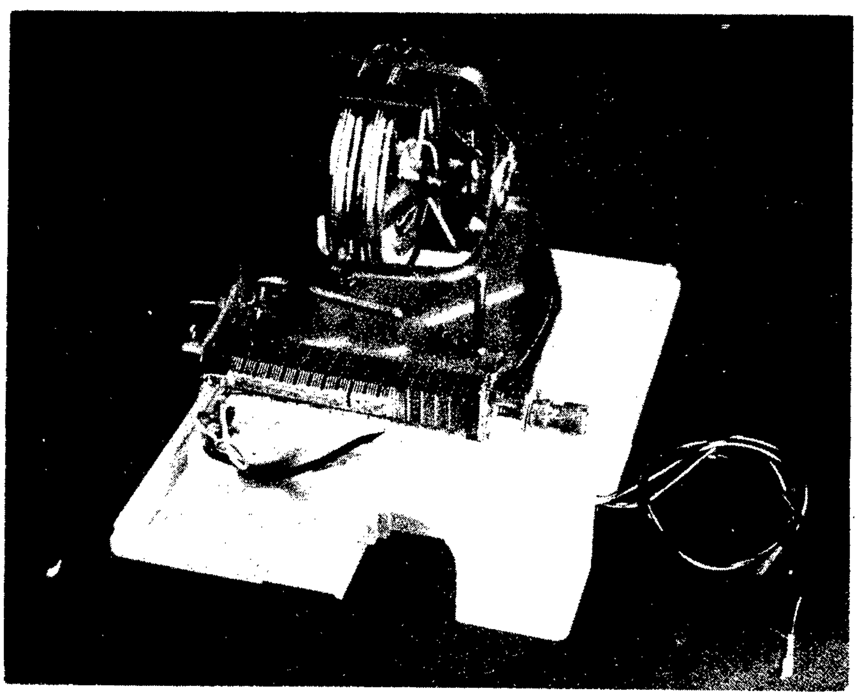


Fig. 12
Flight Termination Switch

When the system again descends to 25,000, the pen arm comes into contact with the commutator contact and an electrical circuit is closed through a squib in the load line. The load line is cut and the load on the system falls six to eight feet before being caught by a supplementary load line. During this fall a rip line pulls a hole one foot long in the side of the balloon and the system descends using the partially inflated balloon to hold the rate of descent to approximately 1200 ft/minute. This system has been used successfully in over 100 flights.

A drawing of the rip assembly is shown as Fig. 13. The cannon and squib to cut the load line are shown as Fig. 14.

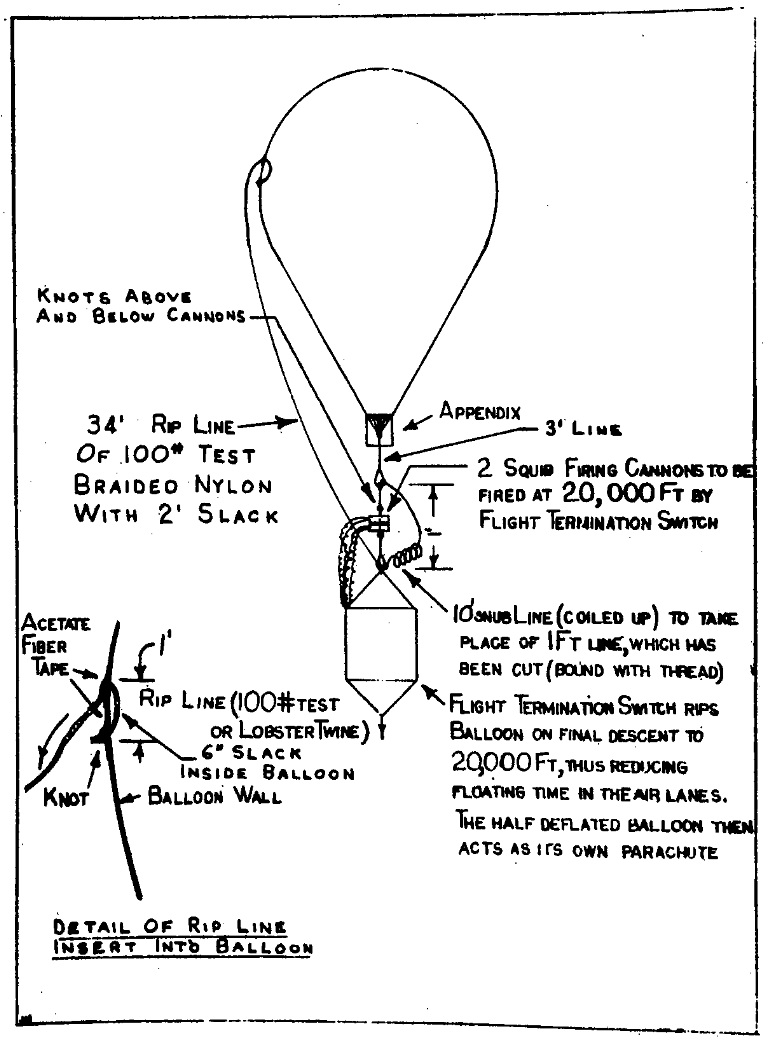


Fig. 13
Balloon Rip Assembly

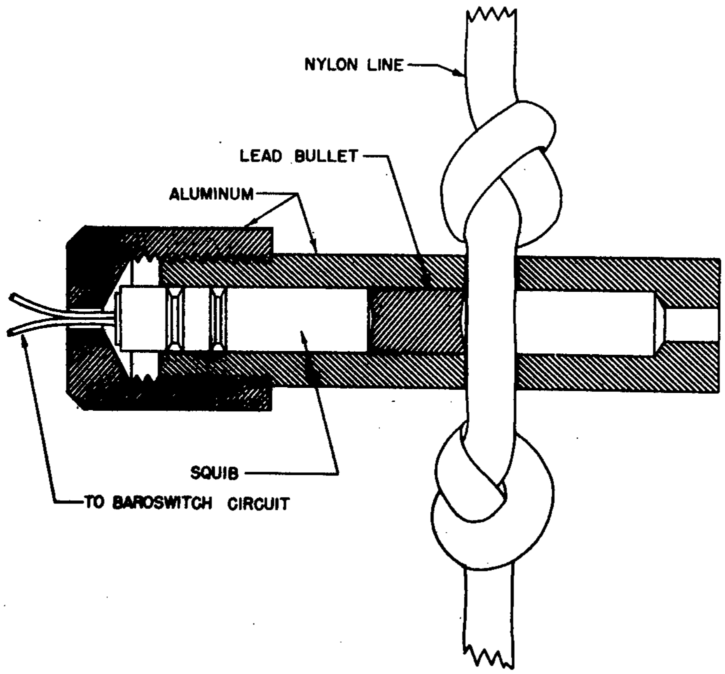


Fig. 14
Rip Assembly Cannon

In all,115 service flights were made under this contract from various government installations throughout the country. A summary of these flights is listed in Table I (see end of text).

E. Meteorological Analysis

As one phase of this project, New York University agreed to prepare analyses of winds and temperatures in the troposphere for dates and localaties specified by Watson Laboratories.

The vertical distribution of temperature from the ground up to heights of about 15 km at the time of any particular experiment was estimated from the routine radiosonde ascents which were nearest in respect to both time and space, to the site of the experiment. If the time of the experiment was within three hours of one of the twice-daily, standard hours of radiosonde observation, the temperature distribution given by such observation was assumed to have existed (within the limits of error in the method of measurement) at the time of the experiment. If the time difference was greater than three hours, a linear interpolation was made between radiosonde observations preceding and following the time of the experiment. Interpolation in space was accomplished ordinarily by assuming a linear horizontal variation of temperature.

However, when weather conditions indicated a markedly discontinuous variation of temperature (i.e. a "front"), appropriate subjective modification of the objective linear interpolation technique was applied.

The vertical distribution of wind was determined mainly from direct observations (pilot-balloon and radio wind-sounding measurements) of free-air winds at weather stations in the area of each experiment. However, actual measurements of winds in the upper half of the troposphere often are scarce or completely lacking, and it was frequently necessary to make use of an indirect method of estimating the wind at elevations greater than 5 km. Charts of the distribution of atmospheric pressure(as given by radiosonde observations) at selected levels between 5 km and 15 km were constructed, and the wind direction and speeds at these levels were computed from the well-known geostrophic wind equation, which relates the wind to the horizontal distribution of pressure.

For the experiments carried out off the east coast of the U.S.A. between 1 August 1946 and 1 August 1947, it seemed feasible to show the distributions of both temperature and wind in vertical cross-section. This was due to the fact that these experiments were made, and the results of same recorded, within a fairly narrow band centered close to a line between Lakehurst, N. J., and Nantucket, Mass., at which points radiosonde and upper-wind observations are taken regularly. However, vertical cross-sections of temperature and wind were abandoned as a method of representation of the distribution pertaining to all subsequent experiments.

There were several reasons for this decision. In the first place, the sites and character of later experiments did not fit into the existing weather-observing network in a manner favorable to cross-sectional representation. In the second place, experience brought about the conclusion that the horizontal gradient of temperature is usually so small that, within the area encompassed by an experiment, the difference in temperature at a given level between points at the ends of a cross-section is no greater than the average error of the radiosonde measurements. Thirdly, it was soon realized that the variability of the wind in space and time is such that an individual pilot-balloon or rawinsonde ascent is not representative of the average vertical distribution of velocity during the interval occupied by a single experiment. Furthermore, as mentioned above, the wind at high levels in the troposphere often had to be inferred by indirect means. Since the true wind usually deviates somewhat from the theoretical geostrophic wind (the latter being derived under certain simplifying assumptions) and since the geometry of the pressure field is subject to some uncertainty owing to inaccuracies in the radiosonde observations, it became apparent that the assignment of a single velocity value at any given point in a cross-section through the atmosphere was misleading.

In order to avoid the suggestion of greater precision than was warranted by the character of the information available, it was decided, during the autumn of 1947 to present the meteorological diagnoses in a different form. Since that time, graphs (in lieu of cross-sections) have been constructed to show the vertical distributions of the estimated ranges, that is to say, the estimated extremes of temperature and wind on the whole or over a part of the area involved in each experiment.

Since August, 1950, the principal task has been the preparation of diagnoses of conditions existing during experiments being conducted regularly in eastern Colorado, western Nebraska and western Kansas by the Industrial Research Institute of the University of Denver. The design of these experiments necessitates a particularly careful study of the available weather data and the exercise of a considerable amount of synoptic meteorological judgment in the preparation of the wind and temperature diagnoses.

F. Flights Utilizing the Constant Level Balloon System

After completion of the balloon control and telemetering development phases of the project, the balloon systems were utilized under Contracts AF 19(122)-45 and AF 28(099)-10, between this University and the Air Force Cambridge Research Laboratories. A brief review of these projects is as follows:

1. High Altitude Balloon Trajectory Study (Contract AF 19(122)-45)

Under the terms of this contract the Research Division was commissioned to launch and track constant level balloon systems in order to study wind conditions at the 200 mb level of the atmosphere. Flights were to remain afloat until they had traveled approximately 1000 miles.

In order to track the balloon systems, the AM-1 transmitter was operated at 1746 kc, using the radio compass from an aircraft to "home in" on the balloon and position it at specified time intervals. Information on pressure altitude, ballast flow data and balloon, free air and transmitter battery pack temperatures was transmitted through the AM-1 to receivers mounted in the aircraft and recorded on brush recorders for analysis at New York University.

A total of 22 flights (two of which crossed the Atlantic Ocean and were recovered in Norway and Algeria) were made on this project. A complete report of these flights and the equipment used is included in "Technical Report 121.01"(6) by this Research Division.

2. High Neutron Intensity Study (Contract AF 28(099)-10)

In conjunction with a study to determine the altitude of maximum neutron density a modification was made on the Constant Altitude balloon system developed under this contract. In order to study neutron densities at two different altitudes with the same set of instruments, it was desirable to carry these instruments through a "stepped flight". The balloon system in this case was to ascend to a selected altitude (say 45,000 ft.) float there for one hour and then ascend to a higher altitude (for example 65,000 ft.) to float for another hour before descending.

The advantages of this type flight for Cosmic Ray studies are that a given altitude may be sampled for a long enough period of time to obtain statistically valid results, and such statistical sampling can be made at several levels without the necessity of releasing another balloon system and other set of neutron sensing instruments. By proper design of equipment a fairly wide range of altitudes can be sampled with "altitude steps" of almost any desired size.

The step effect is attained by release of a fairly large amount of ballast at a fast rate set off by a pre-set clock timer or a radio release activated by a transmitter on the ground. The amount of ballast to be released is determined from the standard altitude-volume load relationships used for constant-level balloon flight. As a part of the final ballast release, the ballast tank and its controls may be dropped from the system.

If the level positions of the flight must be controlled to fine limits, or if they must be of long duration (more than two hours) it is necessary to employ constant-level ballast control over these portions of the flight. However, if the level portions of the flight are to be in the neighborhood of 1 hour duration, ballast control during these floating periods can be eliminated, making use of the inherent stability of the plastic balloon systems for short range constant level flights. It is this latter method which was used by the New York University group in the study of Neutron Maxima.

In this study four flights were made to study conditions at altitudes of 45,000 and 60,000 ft. A clock timer was set to cause release of ballast after the system had floated at the lower level for one hour. After ballast was expended the timer caused release of the ballast tank to further reduce the load on the systems. A typical flight of this series is shown as Fig. 15. Further details on this study have been given in reports on "Neutron Intensity Study"(5) by this Research Division.

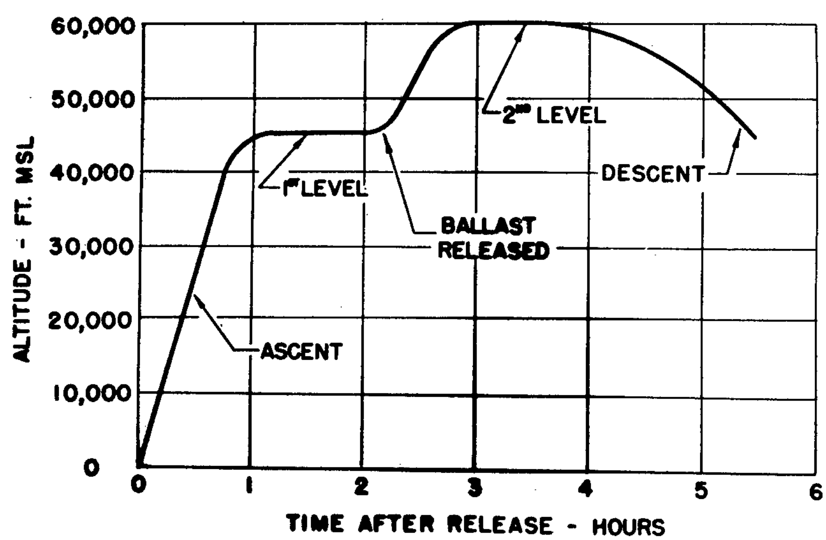


Fig. 15
"Two Level" Stepped Flight

Flight No.	Date	Release Point	Altitude in ft.	Recovery
MXF-1	5/13/48	Maxwell Field, Ala.	60,000	
" -2	5/14/48	" " "	55,000	
" -3	5/14/48	" " "	did not reach altitude	Tyler, Ala.
" -4	5/14/48	" " "	55,000	
E-CW-400-2	7/23/48	Eglin AFB, Fla.	45,000	
" " " -3	8/23/48	" " "	45,000	
" " " -4	8/24/48	" " "	45,000	
" " " -5	8/25/48	" " "	45,000	
" " " -6	8/25/48	" " "	45,000	
" " " -7	8/26/48	" " "	45,000	
" " " -8	8/30/48	" " "	45,000	
" " " -9	8/31/48	" " "	45,000	
" " " -10	9/2/48	" " "	45,000	
" " " -11	9/2/48	" " "	45,000	
" " " -12	9/8/48	" " "	45,000	
" " " -13	9/10/48	" " "	45,000	
" " " -14	9/13/48	" " "	45,000	
" " " -15	9/29/48	" " "	45,000	
" " " -16	9/30/48	" " "	45,000	
" " " -17	11/1/48	" " "	45,000	
" " " -18	11/4/48	" " "	45,000	
" " " -19	11/4/48	" " "	45,000	
" " " -20	11/8/48	" " "	45,000	30° 26' N 86° 29' W
" " " -21	11/8/48	" " "	45,000	
" " " -22	11/9/48	" " "	45,000	
" " " -23	11/15/48	" " "	45,000	
" " " -24	11/15/48	" " "	45,000	
" " " -25	11/16/48	" " "	45,000	
" " " -26	11/17/48	" " "	45,000	
" " " -27	11/18/48	" " "	45,000	12 mi.W.,Fitzgerald, Ga.3:30 P.M. 11/18/48
" " " -28	11/18/48	" " "	45,000	
" " " -29	12/1/48	" " "	45,000	
" " " -30	12/9/48	" " "	45,000	
" " " -31	12/11/48	" " "	60,000	
" " " -32	12/12/48	" " "	62,000	
" " " -33	12/14/48	" " "	65,000	
" " " -34	12/16/48	" " "	65,000	
" " " -35	12/17/48	" " "	65,000	
" " " -36	1/13/49	" " "	Test	
" " " -37	1/13/49	" " "	50,000	
" " " -38	1/14/49	" " "	50,000	
" " " -39	1/15/49	" " "	50,000	
" " " -40	1/28/49	" " "	No release	

Flight No.	Date	Release Point	Altitude in ft.	Recovery
E-CW-400-41	1/28/49	Eglin AFB, Fla.	60,000	
" " " -42	1/28/49	McDill AFB, Fla.	50,000	
" " " -43	2/16/49	Avon Park, Fla.	48,000	
" " " -44	2/17/49	" " "	50,000	
" " " -45	2/18/49	" " "	48,000	
" " " -46	2/21/49	" " "	55,000	
" " " -47	2/22/49	" " "	50,000	
" " " -48	2/22/49	" " "	40,000	
" " " -49	2/23/49	" " "	42,000	
" " " -50	2/23/49	" " "	Equipment failure	
" " " -52	2/24/49	" " "	50,000	
" " " -53	3/2/49	" " "	45,000	
" " " -54	3/3/49	" " "	Instrument failure	
" " " -55	3/3/49	" " "	50,000	
" " " -56	3/4/49	" " "	50,000	
CL-1	6/7/49	Clovis AFB, N.M.	45,000	
" -2	6/10/49	" " "	45,000	
" -3	6/10/49	" " "	45,000	
" -4	6/14/49	" " "	45,000	Graham, Texas
" -5	6/14/49	" " "	45,000	
" - 6	6/16/49	" " "	50,000	
" -7	6/23/49	" " "	50,000	Sayre, Okla.
" -8	6/23/49	" " "	55,000	
" -9	7/19/49	" " "	50,000	Portales, N.M.
" -10	7/21/49	" " "	50,000	
" -11	7/21/49	" " "	50,000	
" -12	9/26/49	" " "	50,000	Marlow, Okla.
" -13	10/6/49	" " "	50,000	La Mont, Okla.
" -14	11/18/49	" " "	50,000	Frankel City, Texas
" -15	11/30/49	" " "	50,000	
" -16	12/2/49	" " "	50,000	
" -17	12/6/49	" " "	50,000	Boonville, Miss.
" -18	12/8/49	" " "	50,000	Fort Douglas, Ark.
EN-1	1/23/50	Vance AFB, Okla.	50,000	Centralia, Ill.
"-2	1/31/50	" " "	50,000	Nevada, Mo.
"-3	2/2/50	" " "	50,000	Moore's Hill, Ind.
"-4	2/9/50	" " "	50,000	Sheridan, Ky.
"-5	2/9/50	" " "	50,000	Pt.Hillford, Nova Scotia, Can.
"-6	2/9/50	" " "	50,000	Jonesboro, Me.
"-7	2/14/50	" " "	50,000	Perkins, Okla.
"-8	2/14/50	" " "	50,000	Winchester, Ontario, Can.

Flight No.	Date.	Release Point	Altitude in ft.	Recovery
EN-9	2/17/50	Vance AFB, Okla.	55,000	Washburn, Mo.
" -10	3/3/50	" " "	50,000	
KN-1	4/25/50	Sedalia AFB, Mo.	50,000	
" -2	5/12/50	" " "	55,000	Booneville, Mo.
" -3	5/26/50	" " "	55,000	Warrensburg, Mo.
" -4	5/26/50	" " "	40,000	Concordia, Mo.
" -5 Hi.	6/2/50	" " "	50.000	Wapella, Ill.
" -5 Lo.	6/2/50	" " "	40,000	
" -6 Hi.	6/20/50	" " "	50,000	Ashtabula, Ohio
" -6 Lo.	6/20/50	" " "	40,000	
" -7 Lo.	7/11/50	" " "	40,000	Springdale, Ark.
" -7 Hi.	7/11/50	" " "	50,000	
" -8	7/14/50	" " "	40,000	Loysville, Pa.
" -9	7/24/50	" " "	50,000	California, Mo.
" -10	8/31/50	" " "	50,000	
" -11	9/14/50	" " "	48,000	Shelbyville, Tenn.
" -12	9/14/50	" " "	45,000	La Monte, Mo.
" -13	9/22/50	" " "	52,000	
" -14	9/28/50	" " "	48,000	Louisianna, Mo.
" -15	10/5/50	" " "	48,000	
" -16	10/10/50	" " "	45,000	
" -17	10/12/50	" " "	45,000	Marshall, Mo.
" -18	10/17/50	" " "	45,000	
" -19	10/26/50	" " " .	50,000	Dickson, Tenn.

In addition service flights were made from Watson Laboratories,AMC Eatontown, N.J., for testing of items of geophysical equipment during the course of the project.

During June, 1949, service flights were made from Luke AFB, Arizona, simultaneously with those made from Clovis AFB, New Mexico.

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